Providing Collaborative Education with an International Dimension: An Ulster University and Pennsylvania State University Case Study (J)

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Providing Collaborative Education with an International Dimension:
An Ulster University and Pennsylvania State University Case Study

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ABSTRACT

The BIM process, encompassing the use of Common Data Environments (CDEs), collaborative working and the sharing of approved, up-to-the-minute information, has revolutionized the construction industry. However, this method of delivery is something which is alien to many needing a paradigm shift in communication methods (Homayouni et al, 2010), as most are more familiar with traditional approaches such as email communication and sharing communication and sharing 'marked up' hard copies of drawings. In the technology driven world in which we live, it is important that those entering the industry from this point forward have an appreciation of this way of working. Therefore, this paper will provide an overview of a collaborative project which has been undertaken at Ulster University to help undergraduate students become familiar with this new way of working and communicating. The paper will outline how the students worked in multidisciplinary teams on a hypothetical building project, before collaborating asynchronously with students from Pennsylvania State University.

KEYWORDS

BIM, Collaboration, Collaborative Working, Education

1. INTRODUCTION

The Belfast School of Architecture (BSA) and the School of the Built Environment (SCOBE) sit within the Faculty of Art, Design and the Built Environment at Ulster University (UU). There are a range of construction related undergraduate programmes situated within both schools, including Architectural Technology & Management (ATM) within BSA and both Civil Engineering (CE) and Quantity Surveying and Commercial Management (QSCM) within SCOBE. Within BSA the implementation of BIM ideology is most apparent on the ATM programme. Architectural Technology is a "relatively new professional discipline" (Emmitt, 2002), which is constantly evolving. It is likely to evolve further over coming years to meet the requirements of BIM and associated working methods (Morton & Thompson, 2011), and play a key role in the future delivery of BIM projects. Matthews (2013, p.191) indicates that Architectural Technologists "core education is technical design and this gives them a skill set that allows them to communicate effectively with the other design disciplines to in effect provide a central point of co-ordination for building information". Therefore, integration of BIM concepts, principles and processes are essential within the curriculum to ensure graduates are ready to meet the challenges they will face in industry.

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In contrast, Civil Engineering is the second oldest engineering profession after military engineering. However, it also needs to move with the advances in technology as it deals with all aspects of the built environment: structural design, environmental and geotechnical aspects of construction, highways and transportation, municipal engineering including waste and clean water, materials and costal engineering. Sacks & Barak (2010) determine that in this environment where numerous disciplines intersect and interact, communication is vital to the success of a project. They further indicate that should BIM not be included in the undergraduate curricula, graduate civil engineers will not have the ability required for expression and communication of design intent. Therefore, communication of the structural design elements through collaborative practice is a vital success factor in any project.

Within the Quantity Surveying (QS) discipline, many journal articles over the past three to four decades predicted that technological advancements such as: the development of intelligent software systems like ELSIE in the late 1980s (Brandon, 1992); widespread use of spreadsheets in accountancy and surveying and database driven Bill of Quantity description libraries in the 1990s (Saleh, 1999); two-dimensional on screen Quantity-Take-Off (QTO) in the early 2000s (CRC Construction Innovation, 2007) and now BIM (Wong et al, 2014; Wu et al, 2014), would eradicate the role of the Quantity Surveyor in building procurement. Far from this being the case, the number of registered Quantity Surveyors in the United Kingdom (UK) has risen over that period and it remains by far the largest representative group of surveyors within the Royal Institution of Chartered Surveyors (RICS). This is most likely due to employers throughout the industry recognising:

- The commercial value of obtaining the correct commercial advice and matching the correct procurement options to the client's needs to ensure a positive impact on team performance (Forgues & Koskela, 2008).
- The benefit of setting up the contract particulars to deliver the outcomes the client demands (Ramus et al, 2006)
- The value of impartial advice on the validity of claims for variations, loss and expense, extensions of time and agreeing final accounts. (Ramus et al, 2006)
- The requirement for similar (commercially aware) advice to contractors and sub-contractors alike, regarding the preparation of tenders, their financial risk management and entitlements, maintaining positive cash flow, monitoring profitability and assisting in contingency planning to mitigate losses (Ren et al, 2001).

The requirement for such professional services is unlikely to dissipate in the near future, even if clients overcome their aversion to Integrated Project Delivery (IPD) approaches that BIM also champions (Kent & Becerik-Gerber, 2010). The profession sees BIM as an opportunity to access the geometrical data associated with intelligent models more quickly and efficiently (Cheung et al, 2012), allowing the Private Quantity Surveyor (PQS) more time to consider other import aspects including better value engineered design optimisation and enabling faster decision turnaround, thus providing a better service. The challenge is not so much whether the QS should embrace BIM or if it should be introduced within the curriculum, but how it should be taught and delivered within a collaborative approach to educational delivery.

Since the Latham report (Latham, 1994) highlighted the immense fragmentation within the construction industry design teams have started to incorporate contractors in integrated design teams (Baiden et al, 2006). Greater emphasis has been given to the communication of ideas and BIM is the ideal mechanism to deliver this. Prior to this it had been deemed a problem due to the temporary nature of the alliances between team members in design and construction due to the cross-organizational boundaries this produces (Dossick & Neff, 2010). However, BIM is promoted as the way to overcome these issues.

This paper will focus specifically on the related programmes in these discipline areas and highlight collaborative working practices that have been developed to aid understanding of the BIM process and project workflow. It will firstly provide an overview of a collaborative project that was delivered to ATM and QSCM students in the 2013/14 academic year, before being enhanced in the 2014/15 academic year to include CE students at UU and students from Pennsylvania State University (PSU) in the United States. This provided an international dimension and was facilitated via the use of a leading industry standard Common Data Environment (CDE). Udeaja & Aziz (2015) highlight BIM based collaboration in education between construction disciplines as an important area, with employers requiring graduates with these skills. However, they also state that "the education sector is falling behind" in terms of implementing multidiscipline collaboration in general. Therefore, the rationale for this paper is to provide a case study example of how multidisciplinary working has been implemented in practice, utilising the BIM process as a driver.

2. DELIVERING A COLLABORATIVE APPROACH

Collaboration is the top ranked driver for implementing BIM according to Eadie et al (2013). The importance of collaboration is supported by findings from the UK and Irish Construction industries, with a small scale study, albeit exploratory, showing that 80% of Irish construction industry respondents "felt that collaborative approaches to management of their supply chains were either Critical (36.96%) or Important (43.47%) to their organisations" (Taggart et al, 2012, p.691). The study referred to similar research undertaken for the UK construction industry (Akintoye et al, 2000), the result of which was comparable, showing "90% support for important or critical." (Taggart et al, 2012, p.691)

However, as already alluded to in this paper, there is a feeling that educational institutions in general are not adopting a multidisciplinary collaborative team mentality within their programme design and module content. Macdonald (2011) referring to other studies, (Becerik-Gerber et al, 2011; Allen Consulting Group, 2010; Forgues et al, 2011), outlined, "universities are lagging behind the construction industry in terms of adopting BIM technologies and improved collaborative working practices." Barison & Santos (2010), examining BIM integration into the curricula in the USA and elsewhere highlighted, "Most schools introduce BIM in only one discipline (90%) and few are trying to simulate the integrated practices: interdisciplinary (7%) and distance collaboration (3%)". Therefore, it would appear that even in countries such as the USA, where BIM implementation is generally considered to be advanced, there appears to have been a historic lack of collaboration between disciplines and distance collaboration within the AEC curriculum. This is something to be addressed, especially in light of the suggestion by Kymmell (2008), as cited in Barison & Santos (2010), that "The fundamental BIM concept to be taught and learned is collaboration."

However, there may be good reason for this historic lack of collaboration between disciplines and distance collaboration. In terms of BIM integration, there are many educational challenges, such as "difficulties in learning and using BIM software; misunderstanding of the BIM process and issues related to the circumstances of the academic environment." Kymmell (2008) as cited in Barison & Santos (2010).

Collaboration between disciplines can sometimes also be hampered by the hierarchical structure within higher education institutions. Architectural, Engineering and Construction (AEC) programmes are often situated within different schools, sometimes in different physical locations, making collaboration more challenging due to logistical and timetabling issues.

There is also the debate as to whether institutions should be teaching specific BIM software programs or developing the students understanding of BIM theory and process. Ku & Taiebat (2011) fuel this discussion suggesting industry concentrate more on employing students with a deep conceptual knowledge of BIM rather than those only skilled in using BIM software programmes. Hietanen & Drogemuller (2008), as cited in Barison & Santos (2010), also highlight the importance of the concept over the software. As it is inevitable that software programs will change and develop over time, there is a feeling among many academics that teaching the software should be secondary to instilling an understanding of the basic principles. Indeed, many would argue that the teaching of specific software should be outside of the core curriculum. However, this viewpoint needs to be balanced against the requirements of industry. Undergraduate courses that incorporate a period of industrial placement rely on practices offering placement positions to their students. These practices expect students to have a working knowledge and understanding of BIM software programs. If they do not, it could potentially lead to problems in obtaining relevant placement experience.

It should be remembered that BIM collaboration is through the software element. Therefore, teaching the software is important in providing an overall context to BIM. This is also important in ensuring that students have an appreciation of the range of software, collaborative platforms, and general BIM technologies which are available. In addition to this, an appreciation of the interoperability of software is also required in teaching BIM, as the advent of OpenBIM and the 2016 target for BIM use on all Government construction projects has led to a proliferation in different BIM software programmes (Eadie & McClean, 2015). This is further complicated by the large number of design and construction disciplines within construction, each having individual processes using different software packages making collaboration difficult (Marshall-Ponting & Aouad, 2005).

Contrary to this, it appears that many institutions are over reliant on teaching BIM software, which in turn can lead to a reduction in time for collaboration with other disciplines. All of these issues need to be debated and addressed before a fully collaborative BIM educational plan can evolve and be implemented in practice.

3.THE FORMAT OF COLLABORATION

The "transition strategy" for implementing BIM within the higher education sphere in general is still being debated, see Underwood and Ayoade (2015, p.28), along with the ideal delivery format of BIM and associated collaborative working practices. This paper seeks to examine the aspects of collaboration through experiential practice through a CDE. A number of possible approaches to collaborative delivery were considered such as; 1. collaboration between disciplines within the same institution, 2. collaboration between disciplines in other institutions (including international collaboration), and 3. collaboration with industry professionals to simulate real life projects, or a combination of the aforementioned. While the option of industry input would have been preferable, the case studies concentrated on the first two options above and a combination of these options.

Mindful that, "the construction industry worldwide is beginning to move towards collaborative design practices as a means of improving project quality and certainty" (Macdonald, 2011), the concept of collaboration needs to be given greater consideration if higher education institutions are to best prepare students for the real world of work and replicate real world practice. This has been further highlighted in a recent study undertaken by the authors of this paper from Ulster University, which once again outlined the importance of collaboration in BIM education (Eadie et al, 2014). It was against this backdrop that a collaborative project was initiated to provide students with an opportunity to work in a collaborative manner, thus enhancing their knowledge and understanding of BIM processes. At the same time the project provided the academics involved with an opportunity to deliver a collaborative project and determine how this could be best delivered at their institution

4. METHOD USED

4.1. Method Background

This paper reports on learning from two case studies set out in the next sections. Eisenhardt (1989) suggests that case studies are one of the best ways to understand the dynamics present within single settings. Fellows & Liu (2015) state, "Case studies encourage in-depth investigation of particular instances within the research subject." The case study methodology was therefore particularly suited to this type of qualitative study as it enabled observations to be noted during the course of the projects and learning to take place from a live project experience. With the information and observations taken over two academic years it allowed for more robust conclusions to be drawn. The first case study examined the collaboration within departments in 2013/14 and then this was further expanded by the introduction of the Civil Engineering discipline and international collaboration with Penn State University in 2014/15. These case studies used a design and build project which is described in the case study.

4.2. Software Used

It has been shown that within the UK that over the period of the case studies that Autodesk Revit (Autodesk, 2016) was the most widely used software for creation of BIM models (Eadie & McClean, 2015, Eadie et al, 2014b). Ulster University adopted this software and it was installed in two laboratories with over 80 computers. Autodesk Revit was used during both studies, with the ATM students using this software in the creation of the initial models. CE students refined the models and carried out analysis using Masterseries software.

The Masterseries suite (Masterseries, 2016) of design programmes was used to allow the Civil Engineering Students to carry out the structural design. This software is one of the UK's leading analysis packages. It covers a structural analysis, design, drafting and detailing. The software was initially created by members of staff at Ulster University and now independent, it has over 10,000 users worldwide. It has a module that allows interaction between the analysis section of the software and the Autodesk Revit BIM model. In this project it allowed CE students to export a beam created in Autodesk Revit Structure to be analysed, the revised section was then imported back into the model with the model automatically updating on import.

The QSCM students used Causeway BIM Measure (Causeway, 2016), Microsoft Project and Navisworks software (Autodesk, 2016b). These platforms were used for creation of priced documents and simulations respectively. Causeway BIM Measure was adopted for quantity take-off due to its capacity to measure from individual models or those combined from a number of consultants known as federated BIM models. This makes it ideal for a collaborative project.

The PSU students had the option of using Leica TruView software (Leica, 2016) to analyse the existing site, and for assistance when creating the landscape model. To aid project workflow, the models were made available in a number of file formats including IFC. IFCs were established by the International Alliance for Interoperability (IAI) in an attempt to ensure data compatibility across the different software programmes. Buildingsmart (2016) state that IFC format is now an international standard registered by the International Standards Organisation (ISO) as ISO 16739 (AUGI, 2012). Nearly all of the major BIM software providers provide IFC support, which in theory should allow transfer of data between the various software packages (Eadie & McClean, 2015). These can be shared through a CDE.

One of the CDE's used for sharing and viewing data is Asite (Asite, 2016). It is a software platform that specialises in document management, project management, sourcing, e-procurement, and collaborative BIM. This package has many advanced features, however for the most part the students only used it for accessing the models for mark-up and for general discussion. Asite was the platform used for the delivery of the project in the 2014/15 academic year. In the previous year the university's own Virtual Learning Resource was used to simulate the CDE. A comprehensive overview, analysis and comparison of CDE delivery is outside the scope of this paper, but can be found in Comiskey et al. (2016).

4.3. The Project

Details of the project that the students collaborated on are provided in Section 5.

5. THE DESIGN & BUILD PROJECT

5.1. Ulster University Collaboration 2013/2014

In the 2013/14 academic year it was decided to implement a collaborative project, which would initially be delivered to students on both the ATM and QSCM programmes. With the 2016 BIM mandate leading to a growing appetite within the local construction sector, it was felt that the development of such a project was important in ensuring that students about to undertake their period of industrial placement had an understanding of the BIM process and experience of collaborative working. As this was to be a pilot project, it was decided that small-scale collaboration between two programmes would work best. Delivery at Level 5 (Year 2) was proposed; as the module marks would not contribute to the students overall degree classification. With the two programmes involved being in different schools, a number of logistical challenges had firstly to be overcome. These included:

- Sourcing a suitable module on both programmes that would allow collaboration to take place (the programmes did not have any shared modules).
- Scheduling a time for the collaborative lessons to take place that suited both cohorts.
- Ensuring students met up outside of scheduled lectures to work collaboratively in their teams, and sourcing a suitable space for them to do so.
- The ATM students outnumbering the QSCM students by a ratio of 2:1.

However, the most pressing challenge was in developing a project brief that would both link with an existing module on both programmes and successfully deliver the learning outcomes required. It should be noted that in previous academic years the students had only performed discipline specific tasks within their individual modules and had not worked in a collaborative manner.

After a series of meetings between the academics involved, two modules were identified for which it was thought, the coursework requirements could be amended to include a collaborative aspect without unduly impacting upon the module learning outcomes. This was important, as one of the aims at the project outset was to demonstrate how collaborative working could be integrated into existing programme delivery quickly without the need for complicated programme or module redesign. A brief, framed around the learning outcome goals, was developed which focused on a design and build bid team preparing contractors proposals in response to a client invitation to tender for a Sports Pavilion (to be located on the University grounds to aid project realism).

The ATM students used Autodesk Revit to create their architectural model. The models were developed from a set of two-dimensional drawings, created in Autodesk AutoCAD, in a semester one module in which the students were required to consider building control requirements and technical details for the same scheme. The QSCM students utilised Causeway BIM Measure for 5D Quantity Take Off and Estimating, as well as Navisworks for 4D Construction simulations and importing Microsoft Project programmes.

The collaborative aspect came in the formation of project teams, with each team having two ATM students and one QSCM student, and in the use of a CDE derived from the Virtual Learning Environment (VLE) used at UU. Collaborative working practices were also demonstrated in using Navisworks software to save views and use the red line mark-up tools to ask and respond to queries. At the time the academics involved had no experience of using a CDE, but based upon their understanding of its purpose and structure, customised the University's VLE to act as a cloud based file repository with the basic structures defined in BS1192:2007 (BSI, 2007) and PAS1192-2:2013 (BSI, 2013). Indeed, the students were encouraged to use the file naming convention outlined in both documents throughout the duration of the project.

The students used the tools and processes, with stipulated phased completion deadlines, to share their initial models, prepare requests for information and answer queries. Initial tender programmes and budget costs were fed back to ATM students to facilitate optimised designs to meet the brief. The students then presented their schemes to the 'client' at the end of the semester. The project received excellent feedback, generating interest both within the university and from industry, and led to a leading construction contractor offering to sponsor a prize for the winning team.

5.2. Collaboration with Penn State University

The success of the initial pilot project and the initial vision to expand the collaboration led to an invitation to participate to students enrolled on the CE programme at UU and the Landscape Architecture programme at PSU (with students from the architecture and architectural engineering programmes at PSU also subsequently involved at the project outset). The academics associated with both programmes were presented with an overview of the initial project and were keen to participate to further their own understanding and to provide their students with a unique learning opportunity.

To provide the students with a more realistic project experience, and to build on the progress made during the pilot project, a number of CDE service providers were approached to get involved with the project. Asite (a leading provider of CDE platforms on many early adopter projects) agreed to allow the use of their CDE platform to host content and for students to experience using the full functionality of a BIM enabled CDE. Leica Geosystems also participated and carried out a point cloud survey of the proposed site with the goal of allowing the ATM students to use it to coordinate their design proposals with a very accurate representation of the existing site constraints.

The general scenario was similar to the previous year, but the brief was amended slightly to request a new student residential block and included a notional set of Employer's Information Requirements (EIRs). The tasks to be undertaken by the ATM and QSCM students were broadly similar to the previous year. The fact that the CE students involved in the project were Level 4 (Year 1), and had a lack of detailed BIM process knowledge, meant that the extent of their participation was limited to accessing the architectural models via the CDE and calculating the sizes of structural members to support openings. However, involvement was still considered beneficial, as it was an excellent opportunity to become familiar with collaborative working practices.

Involvement of the PSU students and academics was critical in adding an international dimension and the various challenges associated with this. Discussions with the academics at PSU took place via email and the Citrix GoToMeeting videoconference facility. This allowed specific project requirements and outputs to be confirmed. It was decided that the task of the PSU students would be to develop landscaping proposals for incorporation into the overall scheme designs (Figure 1).

Ideally the PSU students would have been involved earlier in the process with more input into the overall scheme design, but due to logistical challenges and the fact that this again was a pilot project, it was felt to keep the tasks relatively basic.

Before any collaborative working took place the CDE provider provided training to the academic staff involved. Twenty-eight project areas were also prepared in accordance with the basic BS1192:2007 and PAS 1192-2:2013 folder structures, setting up the access rights for each student from the four programmes involved. This would have proved very difficult to achieve using the University's VLE as was the case in the 2013/14 academic year.

The project logistics were quite difficult, as the student ratios did not align. Each group had 1 ATM student, 1 or 2 QSCM students (depending on numbers), 1 or 2 CE students and 1 landscape architecture student, or acting landscape architecture student, as part of a team of 6 from PSU which also included students from the architecture and architectural engineering programmes. Due to limited PSU numbers, each team of 6 was assigned 5 or 6 groups and undertook one generic site based landscape design, which could be shared with each group. 30 PSU students were scheduled to participate at the project outset.

As per the previous academic year, the ATM students used Autodesk Revit to develop the architectural models (Figure 2).

However, the project brief was amended from the 2013/14 project as the notional BIM Execution Plan (BEP) required the models to be exported as .dwfx and .ifc files for use in the CDE and for

Figure 1. Student landscape example

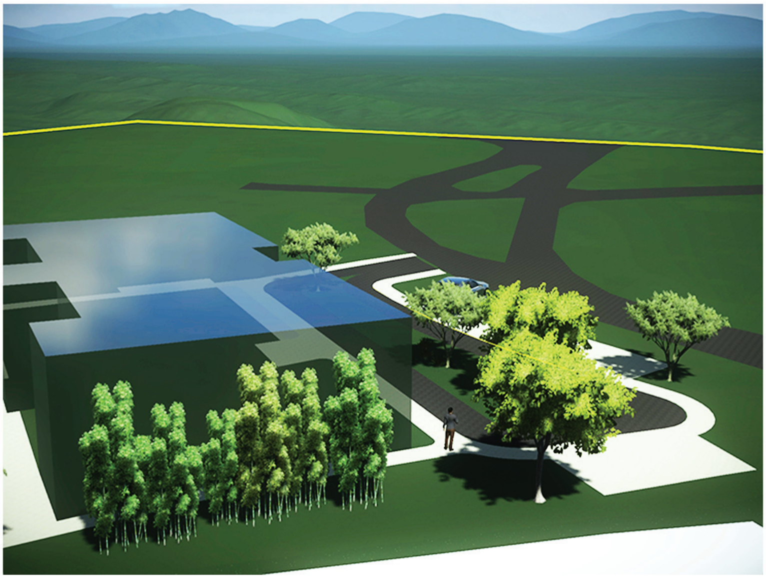

Figure 2. Student Revit model

efficient use on the QSCM's Causeway BIM Measure Quantity Take Off tool. Quantities taken from the model were exported into Excel spreadsheets to create elemental order of cost estimates, where benchmark rates were analysed from the University's online BCIS database. Either Navisworks or the CDE platform was then used to mark-up the model with requests for information and answers to any queries posted. Microsoft Project Gantt charts were imported into Navisworks to create the 4D construction sequencing.

The Civil Engineering students used Revit and Masterseries software to link to the native Revit Architectural models for analysis purposes. Structural elements were exported from Revit into Masterseries, designed and sized and the completed analysis returned into Revit. In terms of PSU input, the initial Revit models of the building and a very basic site plan developed by the ATM students were made available to the PSU students via the 'shared area' of the CDE. This allowed the PSU students to develop their landscaping proposals in Revit. Some also shared their proposals in other formats such as Adobe Photoshop (Figure 3).

Again, the ATM and QSCM students used the CDE to collaborate in developing their joint PowerPoint presentations, which they presented a few days after submitting their contractor's proposals.

6. LESSONS LEARNED

As was the case the initial pilot project, student feedback was generally positive. However, everyone involved, including the academics, learned from issues that developed during the project. These included:

1. Reliance on Participation
2. File formats
3. CDE familiarity
4. Limitations of point clouds
5. Need for common goals to encourage more collaboration

Figure 3. Landscape design

6.1. Reliance on Participation

All the students from the collaborating programmes were dependent upon the ATM students developing the design proposals as 3D digital models. Most dependant were the QSCM students who were not authoring anything, but using the models developed by others for programme and cost analysis. As the student ratios were unequal, this dependence became even more critical.

Model development and sharing via the CDE became a prominent issue in the 2014/15 year as there was a higher than normal number of ATM students presenting with extenuating circumstances, thus resulting in delays in models being shared. This resulted in intervention by the academics who had to coordinate which groups been hadn't provided with the required deliverables on programme and arrange for material to be provided for the dependant students to work on. This disrupted the smooth progression of the QSCM student tasks and placed an additional unforeseen administration burden on the academics. The CE and PSU students were not impacted as much due to the fact that the team formations were resolved by the time they were undertaking their specific tasks.

The issue of reliance on participation was even more apparent with PSU students for several reasons. First, they were not receiving marks for their contributions. Second, they were already engaged in their own IPD studio with landscape architectural, architectural, and architectural engineering students, a studio that dissolved disciplinary silos, where the Ulster collaboration reinforced them. Third, due to the timing and demands of their current IPD studio, only the landscape architectural students were able to provide any meaningful contributions to this collaboration, and of those students, they had limited capacities for working in Revit. Despite motivation from academics regarding the learning opportunity and international prestige of the project, the PSU students did not fully engage in the project with design proposals and visualisations commensurate to those produced for their graded, resident studios.

This was a valuable lesson which demonstrated that consideration must be given to sharing studio goals while providing students with graded assignment that are interdependent to ensure incentivised collaboration.

6.2. File Formats

It is generally recognised that .dwfx is the most commonly used file exchange format in the AEC sector and .ifc is the standard for interoperability being championed by BuildingSmart Alliance International and the UK BIM strategy. However, it is less well understood that the properties of the file export need to be carefully defined with the downstream users of the data in mind (referred to as model definition settings).

The default settings for these export files from Revit resulted in numerous examples of model components not performing as would be expected in downstream tools. For example, the geometry of windows was not accessible in Causeways BIM measure, even though the windows were visible and selectable, their geometry could not be extracted. More care will be required within the EIR to define model definition settings for future projects.

6.3. CDE Familiarity

Asite is a leading industry CDE provider, used on many high profile BIM early adopter projects, and by leading companies. Whilst Asite did all that was asked of them, and indeed more (in providing training and administrative support to help academics become familiar with their user interface, tools and functionality), it became clear that getting the most out of the system and using it to its full potential requires a high degree of familiarity with the system settings (hence one of the drivers for an Information Manager on BIM Level 2 projects). Due to the demands of the academic calendar the staff involved did not have sufficient time to spend familiarising themselves with all of the CDE settings and hence did not use the platform to its full potential. The experience gained from this project has provided both the academics and students with a substantial overview of the workings of a professional CDE platform, and as such, helped to shape and better prepared them for future collaborative projects which are likely to be developed and delivered over the coming academic years.

6.4. Limitations of Point Clouds

The Leica point cloud is very accurate, but not interoperable in its native file format, so needs to be viewed and worked upon within Leica's database system Cyclone. Although a .pts file can be exported from Cyclone which enables data to be used in other software platforms, this creates a very large file size. Hence, a plug-in such as CloudWorx is usually used. The University had only one trial version of this software, and staff had neither the time nor expertise required to export the point cloud into a more interoperable format to be used in Revit and Navisworks. Therefore, this part of the project was abandoned. Further investigation into workflows to make the point clouds more interoperable will be required to develop this option into future projects. However, it should be outlined that some of the point cloud information was utilised via the use of Leica TruView software, a "web-enabled panoramic point cloud viewer", by the PSU students to view the site and get a better understanding of its context in relation to the surrounding university campus.

6.5. Need for Common Goals to Encourage More Collaboration

Collaboration and interdependency was not universally evident within the groups. The assignments and learning outcomes necessarily had to be module specific and therefore retained structural independence within the different programmes, which the students realised. As a result, the level of collaboration, in all but the best groups, was confined to sharing models, programmes, cost analysis within the CDE with little incentive to act upon the feedback. This became evident during the group presentations, which were generally poorly coordinated.

For future projects, additional planning will be required with PSU to ensure their students are involved earlier in the design process to deliver a more realistic IPD type studio where the students are not simply consultants. Another important consideration is the actual physical space available and the layout of classrooms in facilitating collaborative and social learning. With the move towards integrated projects within many built environment disciplines, it is important that there are sufficient areas for students to interact and engage in a collaborative manner and it is important these areas also have adequate technical infrastructure to allow global interaction and engagement.

This feedback and analysis has assisted with a new module proposal within UU at Level 4 (Year 1) that multidisciplinary programmes can incorporate into their structure to provide similar, but enhanced learning outcomes, whilst developing common, interdependent assignment based tasks, which can be differentiated by discipline for assessment.

7. CONCLUSION

Both projects undertaken over the last two academic years have encountered many unique, challenging and unusual problems, but proved to be very worthwhile, providing essential learning for the students and academics alike. The experiences will inform preparations for future projects, with contingencies included to cover some of the circumstances encountered.

At Ulster University, SCOBE recently worked through a cycle of revalidating programmes and the experience acquired from these projects and other research findings helped to inform the design and content of new BIM modules that will be offered to any willing programme. They were designed to be flexible and offer 10 and 20 credit point versions with shared elements such as lectures, tutorials and interdisciplinary assignments, as well as bespoke BIM software elements to encourage maximum collaboration and consistency. The first rendition of the level 4 module has already been delivered, incorporated as a 20 credit point format into the QSCM and a 10 credit point module in the Construction Engineering and Management, Energy and Architectural Engineering programmes. The ATM programme is introducing this module in the current 2016/17 academic year and other programmes have also expressed an interest in incorporating the module within their course structure.

The full potential of the CDE platform was not realised during the project, due to time constraints and the inexperience of the academic team, but both students and academics alike found the exposure to it to be very beneficial. As has already been outlined in the paper, the use of a professional CDE platform in the 2014/15 academic year was beneficial in terms of facilitating the international collaboration with PSU. From an academic perspective, a useful feature was the ability to filter files within project areas. Files uploaded by individual students (who didn't follow instructions requiring copies of their work to be saved in their Work In Progress area before sharing with associated suitability and revision codes) could be easily searched.

The five issues investigated have produced elements that can be generalised in the teaching of BIM collaboratively through a CDE.

In relation to the first of these, "Reliance on Participation", the findings support those of Chan et al (2014) who suggest a more student centred collaborative pedagogical experience should be provided in teaching construction. However, the findings of this study show that the learning can only take place if all the team members contribute and this is more difficult to enforce if they are geographically or organisationally (different programmes/modules) isolated.

The second issue that the paper addressed related to the file formats. Issues relating to interoperability came to the fore, highlighting similar issues to those in Eadie et al (2014b). The case study highlighted that EIR requirements need to be tightened in relation to level of detail to ensure that all elements can be measured. Even when the BEP is explicit, many students are guilty of not appreciating the importance of getting this right until they encounter difficulties in reading the data shared, however, this is a learning outcome in its own right.

The third item related to familiarity with a CDE and training. Hore et al (2016) show that a lead in time was required to allow staff to upskill in BIM software. The case study on the CDE demonstrated a similar process is required on not only the software for created models but the software relating to collaboration as well.

Limitations of point clouds were examined and software and plug-ins specific to certain machines were found to be difficult to manage and created a bottleneck. Care should be taken to choose software that has good interoperability and is user friendly.

The last item investigated relates to the need for common goals to encourage more collaboration. The design of the learning outcomes for each of the disciplines requires the inclusion of common goals to foster the collaboration process. The findings expand on those of Macdonald (2011) where she states that "Ideally, real-world problems will be given to the students to solve". While this is true it is not enough, in addition, students need allocated similar incentives such as the ability to gain marks from carrying out the processes and have the ability to mix in a habitat that allows face-to-face interaction in addition to on-line activity. The projects undertaken over the past two academic years have proved invaluable in shaping understanding of the potential for collaborative working and curriculum development at Ulster University. The positive feedback received from students and industry has demonstrated that collaborative working is both achievable and valuable in terms of curriculum design and delivery.

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REFERENCES

Akintoye, A., McIntosh, G., & Fitzgerald, E. (2000). A survey of supply chain collaboration and management in the UK Construction Industry. *European Journal of Purchasing and Supply Management*, *6*(3-4), 159–168. doi:10.1016/S0969-7012(00)00012-5

ASITE. (2016). Collaborative BIM. Retrieved from https://www.asite.com/adoddle/corporate-collaboration/collaborative-bim

AUGI. (2012). Myth Buster: Revit & IFC. Retrieved from http://www.augi.com/library/myth-buster-revit-ifc

Autodesk (2016). Revit overview. Retrieved from http://www.autodesk.co.uk/products/revit-family/overview

Autodesk (2016b). Navisworks overview. Retrieved from, http://www.autodesk.co.uk/products/navisworks/overview

Baiden, B., Price, A., & Dainty, A. (2006). The extent of team integration within construction projects. *International Journal of Project Management*, *24*(1), 13–23. doi:10.1016/j.ijproman.2005.05.001

Barison, M., & Santos, E. (2010). BIM teaching strategies: an overview of current approaches. In W. Tizani (Ed.) *Proceedings of the international Conference on Computing in Civil and Building Engineering*, Nottingham, UK (p. 577). Retrieved from http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/pf289.pdf

Becerik-Gerber, B., Gerber, D., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: Integrating recent trends into the curricula. *Journal of Information Technology in Construction*, *16*, 411–432.

Brandon, P. (1992). Research and development of expert systems for the construction industry. *Building Research and Information*, *20*(3), 162–165. doi:10.1080/09613219208727200

British Standards Institution (BSI). (2007). *BS1192:2007. Collaborative Production of Architectural, Engineering and Construction Information – Code of Practice*. London, United Kingdom: British Standards Institution.

British Standards Institution (BSI). (2013). *PAS1192-2:2013. Specification for information management for the capital/delivery phase of construction projects using building information modelling*. Retrieved from http://www.buildingsmart-tech.org/specifications/ifc-overview/ifc-overview-summary

Causeway (2016). BIM Measure. Retrieved from www.causeway.com/BIM-Manager/BIM-Measure

Chan, C., & Sher, W. (2014). Exploring AEC education through collaborative learning. *Engineering, Construction, and Architectural Management*, *21*(5), 532–550. doi:10.1108/ECAM-04-2013-0036

Cheung, F., Rihan, J., Tah, J., Duce, D., & Kurul, E. (2012). Early stage multi-level cost estimation for schematic BIM models. *Automation in Construction*, *27*, 67–77. doi:10.1016/j.autcon.2012.05.008

Comiskey, D., McKane, M., Jaffrey, A., & Wilson, P. (2016). Comparing Common Data Environment Platforms for Student Collaborative Working. *Proceedings of theConference of the 6th International Congress of Architectural Technology*, Alicante, Spain.

CRC Construction Innovation. (2007). Final Report: Model Based Estimating System for Civil Concrete Structures. Retrieved from http://digitalcollections.qut.edu.au/1748/1/26838.pdf

Dossick, C., & Neff, G. (2010). Organizational Divisions in BIM-Enabled Commercial Construction. *Journal of Construction Engineering and Management*, *136*(4), 459–467. doi:10.1061/(ASCE)CO.1943-7862.0000109

Eadie, R., Comiskey, D., & McKane, M. (2014) Teaching BIM in a multidisciplinary department. *Proceedings of the 4th International Education, Science and Innovations conference*, Pernik, Bulgaria.

Eadie, R., Heanen, A., & Hall, J. (2014b). Civil Engineering and the Interoperability between Building Information Modelling (BIM) and E-Procurement. Proceedings of the *9th International Conference on Civil Engineering Design and Construction (Science and Practice)*, Varna, Bulgaria.

Eadie, R., & McClean, M. (2015). An Investigation of Interoperability Issues Between Building Information Modelling (BIM) And E-Procurement. *Proceedings of the 5th International Education, Science and Innovations conference*, Pernik, Bulgaria (pp 7-12).

Eadie, R., Odeyinka, H., Browne, M., McKeown, C., & Yohanis, M. (2013). An analysis of the drivers for adopting building information modelling. *Journal of Information Technology in Construction*, *18*, 338–352.

Eisenhardt, K. (1989). Building Theories from Case Study Research. *Academy of Management Review*, *14*(4), 532–550.

Emmitt, S. (2002). *Architectural Technology*. Oxford, United Kingdom: Blackwell Science.

Fellows, R., & Liu, A. (2015). *Research Methods for Construction*. Chichester, United Kingdom: Wiley.

Forgues, D., & Koskela, L. (2008). Can procurement affect design performance? *Journal of Construction Procurement*, *14*(2), 130–141.

Homayouni, H., Neff, G., & Dossick, C. (2010). Theoretical categories of successful collaboration and BIM implementation within the AEC industry. In J. Buwanpura, Y. Mehamed & S. Lee (Ed.) *Proceedings ofConstruction Research Congress 2010: Innovation for Reshaping Construction Practice*, Banff, Alberta (pp.778-788). doi:10.1061/41109(373)78

Hore, A., Scott, L., West, R., & Tibaut, A. (2016). Benefits of Inter-Institutional Collaboration in the Delivery of BIM Education in Ireland: Reflections of an Irish Masters Program. *Proceedings of the 10th BIM Academic Symposium & Job Task Analysis Review*, Orlando, Florida, USA (pp. 152-165).

Kent, D., & Becerik-Gerber, B. (2010). Understanding Construction Industry Experience and Attitudes toward Integrated Project Delivery. *Journal of Construction Engineering and Management*, *136*(8), 815–825. doi:10.1061/(ASCE)CO.1943-7862.0000188

Ku, K., & Taiebat, M. (2011). BIM Experiences and Expectations: The Constructors Perspective. *International Journal of Construction Education and Research*, *7*(3), 175–197. doi:10.1080/15578771.2010.544155

Kymmell, W. (2008). *Building Information Modelling: Planning and managing construction projects with 4D CAD and Simulations*. New York, United States: McGraw Hill.

Latham, M. (1994). Constructing the Team: Final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry. Retrieved from http://constructingexcellence.org.uk/wp-content/uploads/2014/10/Constructing-the-team-The-Latham-Report.pdf

Leica (2016). Leica TruView software. Retrieved from http://hds.leica-geosystems.com/en/Leica-TruView_63960.htm

Macdonald, J. (2011). BIM - Adding Value by Assisting Collaboration. In P. Kneen (Ed.) *Proceedings of LSAA Conference*, Sydney, Australia. Retrieved from http://codebim.com/wp-content/uploads/2013/06/2011_Macdonald_LSAA.pdf

Marshall-Ponting, A., & Aouad, G. (2005). An nD modelling approach to improve communication processes for construction. *Automation in Construction*, *14*(3), 311–321. doi:10.1016/j.autcon.2004.08.018

Masterseries (2016). Company. Retrieved from http://www.masterseries.com/company.aspx

Matthews, M. (2013). BIM Collaboration in Student Architectural Technologist Learning, *Journal of Engineering. Design and Technology.*, *11*(2), 190–206. doi:10.1108/JEDT-10-2011-0067

Morton, P., & Thompson, E. (2011). Uptake of BIM and IPD within the UK AEC Industry: the evolving role of the architectural technologist. *Built and Natural Environment Research Papers, 4*(2), 275-286. Retrieved from http://nrl.northumbria.ac.uk/9405/

Ramus, J., Birchall, S., & Griffiths, P. (2006). *Contract Practice for Surveyors* (4th ed.). Oxford, United Kingdom: Butterworth Heinemann.

Ren, Z., Anumba, G., & Ugwu, O. (2001). Construction claims management: Towards an agent-based approach. *Engineering, Construction, and Architectural Management*, *8*(3), 185–197.

Sacks, R., & Barak, R. (2010). Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education. *Journal of Professional Issues in Engineering Education and Practice*, *136*(1), 30–38. doi:10.1061/(ASCE)EI.1943-5541.0000003

Saleh, M. (1999). The Automation of Cost Estimate: An Improvement in Construction Project Information under Design, Tendering and Execution, *Architectural. Scientific Review (Singapore)*, *42*(4), 253–264.

Taggart, M., Koskela, L., & Rooke, J. (2012). Collaborative Supply Chain Practices During Severe Economic Downturn in the Republic of Ireland. In S.D. Smith (Ed.), *Proceedings of the 28th Annual ARCOM Conference*, Edinburgh, UK (pp. 687-695). Retrieved from http://www.arcom.ac.uk/-docs/proceedings/ar2012-0687-0695_Taggart_Koskela_Rooke.pdf

Udeaja, C., & Aziz, Z. (2015). A case study of fostering multidisciplinary in built environment using BIM. In A.B. Raiden, & E. Aboagye-Nimo (Ed.), *Procs 31st Annual ARCOM Conference,* Lincoln, UK (pp. 701-710). Retrieved from http://www.arcom.ac.uk/-docs/proceedings/431f56cb0e51a3c52d73a1e3179f0f10.pdf

Underwood, J., & Ayoade, O. (2015). Current Position and Associated Challenges of BIM Education in UK Higher Education. *Proceedings of theBIM Academic Forum, 2015*. Retrieved from buildingsmart.pl/baf_bim_education_report_2015.pdf

Wong, P., Salleh, H., & Rahim, F. (2014). The Relationship of Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance. *International Journal of Civil, Environmental, Structural. Construction and Architectural Engineering*, *8*(10), 1031–1036.

Wu, S., Wood, G., Ginige, K., & Jong, S. (2014). A technical review of BIM based cost estimating in UK quantity surveying practice, standards and tools. *Journal of Information Technology in Construction*, *19*, 534–562.

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